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EVALUATION OF THE EXTRAPOLATION FEATURE OF THE TYFOON ANALOG CO--ETC(U)
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EVALUATION OF THE EXTRAPOLATION FEATURE OF THE TYFOON ANALOG COMPUTER PROGRAM

by

LCDR LEO H. CRAIGLOW, JR., USN

MAY 1974

U.S. FLEET WEATHER CENTRAL GUAM
BOX 12 COMNAVMARIANAS
F.P.O. SAN FRANCISCO, CALIFORNIA 96630

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(10) LCDR LEO H. CRAIGLOW, JR, USN

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U.S. FLEET WEATHER CENTRAL GUAM
BOX 12 COMNAVMARIANAS
F.P.O. SAN FRANCISCO, CALIFORNIA 96630

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ABSTRACT

The original version of the TYFOON analog program, first used operationally by FLEWEACEN/JTWC Guam in 1970, has been modified several times to improve its performance. The version used during the 1973 season was known as TYFOON-72. Addition of the 1970 and 1971 tropical cyclone data to the analog data tape plus extension of the storm tracks to the "bitter end" suggested further modifications to the analog program. Elimination of the extrapolation feature plus reduction of the time envelope resulted in the latest version, TYFN73.

A test was conducted, using 1972 data, to determine if the changes incorporated into TYFN73 degraded the forecast positions generated by the analog program. The results of this test revealed no significant differences in forecasting accuracy between TYFOON-72 and TYFN73. In addition, TYFN73 ran over 46% faster. As a result, TYFN73 will be used operationally during the 1974 tropical cyclone season.

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1. BACKGROUND

To prepare tropical cyclone warnings, the Joint Typhoon Warning Center (JTWC) employs a number of computerized objective techniques. Foremost among these techniques is the TYFOON analog computer program. This program compares the parameters of the current storm with those of analog tropical cyclones, extracted from a binary data tape, falling within a predetermined time-space envelope to provide weighted forecast positions for 24-, 48-, and 72-hours and associated 50% probability ellipse forecasts.

The present operational version of the TYFOON analog program, TYFOON-72, was developed by Jarrell and Wagoner (1973) after the 1971 tropical cyclone season. TYFOON-72 considers all analog candidates that fall within $\pm$50 days of the current storm. In addition, if a selected analog storm has insufficient positions to provide a forecast out to 72 hours, the program extrapolates up to four additional six-hourly positions. The extrapolation feature was originally considered necessary because of the premature termination of many of the tropical storms and typhoons contained on the original data tape (1945-1969). On the data tape, tropical cyclones were terminated as soon as they went ashore on the Asian continent. In addition, many of the tropical cyclones were dropped shortly after they recurved towards the northeast. In both situations, most of these tropical cyclones retained their identity for varying periods of time.

During 1972, Ocean Data Systems, Inc., under contract to the Navy Environmental Prediction Research Facility, Monterey, California, modified the original tropical cyclone analog data tape in four respects:

a. All typhoons and tropical storms making land-fall were continued inland until a closed circulation no longer existed.

b. All typhoons and tropical storms which recurved were continued as long as:

(1) The reported winds were 35 knots or greater;

(2) The storm track was south of 50°N; and

(3) The storm retained it's tropical characteristics.

c. All typhoons and tropical storms which occurred simultaneously and approached within 750 miles (Brand, 1968) of each other were eliminated from the data tape. This was due to track distortion caused by the interaction of the two

systems (Fujiwhara Effect).

d. Typhoon and tropical storm data for 1970 and 1971 were added to the data base.

The result was a new analog data tape (1945-1971) that contained not only more data but also more realistic storm tracks.

A research version of TYFOON, TYFN73, was developed within the JTWC after the 1972 tropical cyclone season. The main purpose of this new version of TYFOON was to develop an intensity forecasting scheme based on analogs. Since only intensity was to be examined and time to conduct research on Guam's CDC-3100 computer is limited, the extrapolation portion of TYFOON-72 was removed. Another major change was the reduction of the acceptable time envelope from ±50 days to ±30 days. The larger time envelope had been incorporated into TYFOON-72 to provide a greater sampling of analog storms for off-season tropical cyclones (December-April). Although allowing more analog candidates to be considered, the expanded time envelope also allowed nonrepresentative analog storms at either end of the time spectrum to be included, thereby adversely influencing the TYFOON-72 forecast. However, the smaller time envelope proved to be too restrictive in that insufficient analog candidates were considered, even during some of the climatologically active tropical cyclone months. Therefore, the time envelope was expanded to ±35 days, the same time envelope used in the original version of TYFOON. These two major changes, plus numerous minor changes, resulted in TYFN73.

While conducting intensity research, it was noted that the computer time required for running TYFN73 varied from 20-45 percent faster than TYFOON-72. It thus became important to determine if reduction of the time envelope and elimination of the extrapolation feature degraded the TYFOON analog position forecasts.

2. TESTING PROCEDURE

A total of 15 forecasts were made on 12 separate 1972 tropical cyclones chosen for the test. The 1972 season was selected because the data was not yet on the data tape, which eliminated the "perfect analog" from being considered by the TYFOON program. The 15 forecasts, listed in Table 1, were selected such that three groups of five, each representing a different situation, would result.

Two separate categories of fixes were utilized on three of the systems (Alice, Flossie, and Tess) due to the tracks described. The actual storm tracks, with warning positions indicated, are depicted in Figure 1. As shown, the 12 tropical cyclones provide a representative sampling of tropical cyclone activity in the western North Pacific.

The division of the forecasts into three groups was accomplished using the following criteria:

a. Recurver - those storms that recurved to the northeast during the forecast period;

b. Straight - those storms that moved ashore at some time during their forecast period over the Asian Continent or Japan; and

c. Over Water - those storms that remained over open water throughout the entire forecast period on a basically steady track.

The over water forecasts were used as a control group. Since the tropical cyclones in this group remained over open water and did not recurve during the forecast period, it was felt that the number of extrapolated positions generated by TYFOON-72 should be minimal. This then would give an indication of the efficacy of reducing the time envelope from $\pm$50 days to $\pm$35 days.

The 15 storm positions were then run twice, first using TYFOON-72 and then TYFN73. The expanded, combined analog data tape (1945-1971) was utilized for all runs. Upon completion of the computer runs, deviations from the best track [1] positions were calculated for all forecasts.

1 A post analysis position incorporating all available data.

TABLE 1. TROPICAL CYCLONES SELECTED FOR EXTRAPOLATION TESTING

TYPE	NAME	WARNING TIME
RECURVER	TYPHOON LOLA	311800Z MAY 72
	TYPHOON ALICE	041200Z AUG 72
	TYPHOON HELEN	131200Z SEP 72
	TYPHOON IDA	210000Z SEP 72
	TYPHOON NANCY	170600Z OCT 72
STRAIGHT	TYPHOON TESS	210000Z JUL 72
	TYPHOON ELSIE	010600Z SEP 72
	TYPHOON FLOSSIE	131800Z SEP 72
	TYPHOON PAMELA	050600Z NOV 72
	TYPHOON THERESE	070000Z DEC 72
OVER WATER	TYPHOON PHYLLIS	120000Z JUL 72
	TYPHOON TESS	180600Z JUL 72
	TYPHOON ALICE	030000Z AUG 72
	TYPHOON BETTY	110600Z AUG 72
	TYPHOON FLOSSIE	120600Z SEP 72

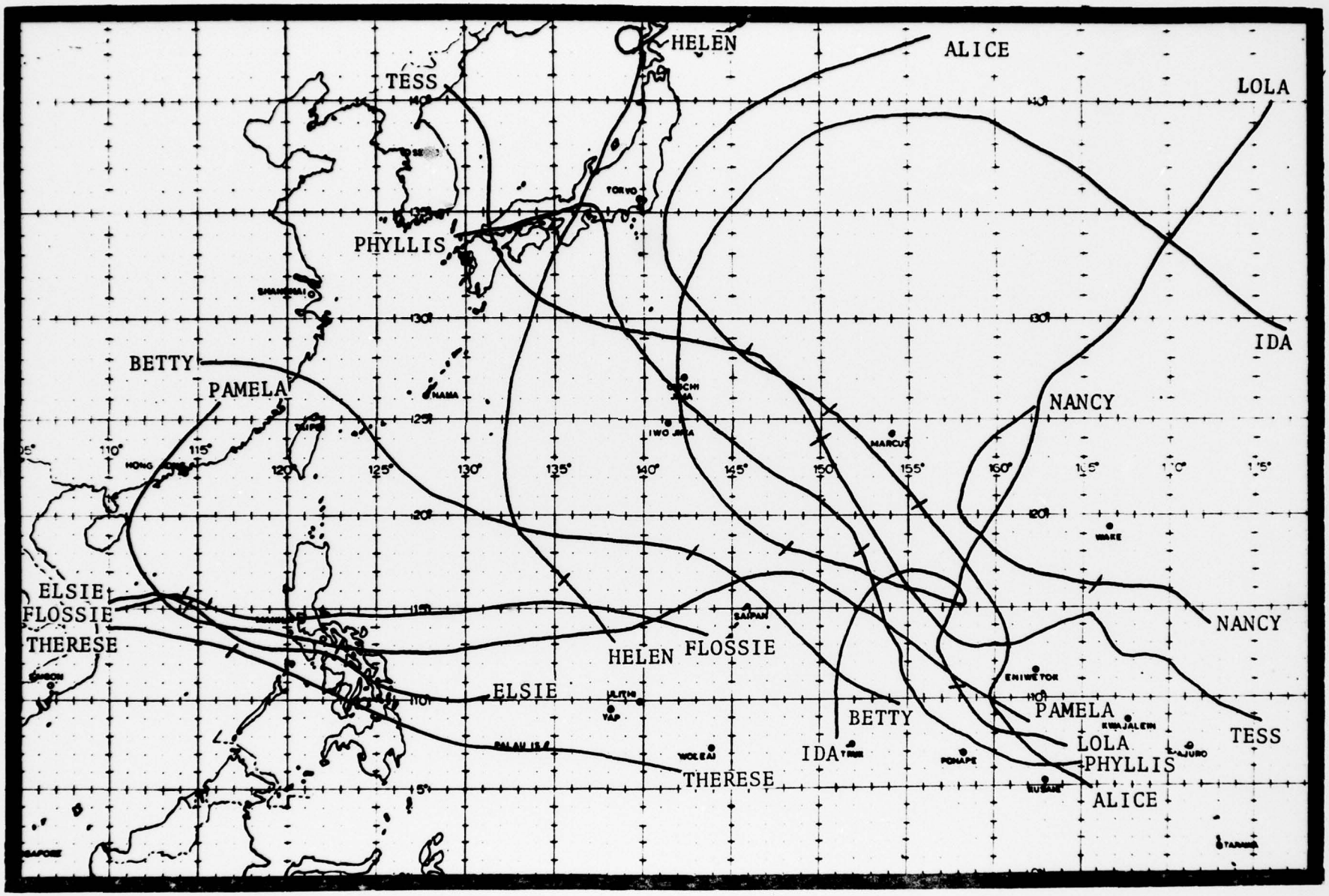

FIGURE 1. 1972 TYPHOONS UTILIZED IN TYFOON EXTRAPOLATION TEST

3. RESULTS

The results of the over water cases are depicted in Table 2. The values in parentheses after the forecast errors in this and subsequent tables represent the number of analog positions employed by each program. In the case of TYFOON-72, the second number indicates the number of extrapolated positions the program generated.

A review of the data presented in Table 2 shows no significant difference between the forecasting skills of the two programs. At all theree time frames TYFN73 was, on the average, slightly better (less than 1.4% max difference). The significant difference was the time required to run each program. In this case, TYFN73 resulted in a 45% savings, which, when faced with limited computer time, becomes substantial.

Table 3 compares the straight error statistics for TYFN 73 and TYFOON-72. Once again, in the mean, there was no significant difference in the two programs at 24 and 48 hours. However, at 72 hours, TYFN73 had an average error that was 14.9% less than TYFOON-72. As in the over water cases, the difference in computer run time was significant with TYFN73 using 48% less computer time.

The recurve error statistics are contained in Table 4. Unlike the previous two cases, significant differences do exist, in the average, between the two programs. At 24 and 48 hours, TYFN73 was superior by 16.3% and 3.3%, respectively. However, at 72 hours, TYFOON-72 was better by 7.9%. Out of the nine separate categories, this was the only time that TYFOON-72 was best. TYFN73 was again faster running; 46% in this instance.

Another item of interest was the large forecast errors at 72 hours for the recurve cases. Only the 72-hour forecast for Typhoon Alice can be considered reasonable. The average 72-hour errors are approximately 150 to 250 nm greater than the 72-hour errors for the other two categories. An analysis of these five forecasts revealed that both programs were too slow in recurving a system towards the northeast. Part of the problem can be attributed to the use of the combined analog data tape wherein straight moving as well as recurving systems are averaged together. In every case, both programs provided forecast positions to the west-westsouthwest of the verifying best track position. Improving the ability of TYFOON to better handle recurving systems involved two major steps:

TABLE 2. OVER WATER ERROR STATISTICS.

NUMBERS IN PARENTHESES ARE ANALOG POSITIONS EMPLOYED BY EACH PROGRAM

STORM	PROGRAM	FORECAST ERRORS (IN NM) 24-HR	48-HR	72-HR
PHYLLIS	TYFN73	134 (32)	313 (32)	415 (30)
	TYFOON-72	142 (47/0)	305 (47/0)	396 (47/2)
TESS	TYFN73	75 (86)	168 (83)	201 (72)
	TYFOON-72	72 (123/1)	163 (122/3)	189 (119/13)
ALICE	TYFN73	101 (51)	195 (51)	360 (48)
	TYFOON-72	106 (75/0)	202 (75/3)	403 (72/5)
BETTY	TYFN73	145 (234)	292 (226)	398 (222)
	TYFOON-72	145 (320/3)	314 (317/8)	441 (309/5)
FLOSSIE	TYFN73	49 (169)	179 (133)	273 (70)
	TYFOON-72	41 (272/8)	177 (264/53)	240 (211/96)
TOTAL	TYFN73	504	1147	1647
	TYFOON-72	506	1161	1669
AVERAGE	TYFN73	100.1 (114)	229.4 (105)	329.4 (88)
	TYFOON-72	101.2 (167/2)	232.2 (165/13)	333.8 (152/24)

TOTAL RUN TIME: TYFN73 5.6 MIN

TYFOON-72 10.2 MIN

TABLE 3. STRAIGHT ERROR STATISTICS.

NUMBERS IN PARENTHESES ARE ANALOG POSITIONS EMPLOYED BY EACH PROGRAM

STORM	PROGRAM	FORECAST ERRORS (IN NM) 24-HR	48-HR	72-HR
TESS	TYFN73	270 (32)	451 (29)	510 (16)
	TYFOON-72	261 (58/0)	404 (58/6)	551 (52/13)
ELSIE	TYFN73	154 (116)	320 (79)	402 (32)
	TYFOON-72	155 (230/18)	370 (212/75)	506 (137/82)
FLOSSIE	TYFN73	92 (181)	188 (121)	---
	TYFOON-72	85 (295/33)	181 (262/88)	---
PAMELA	TYFN73	124 (103)	192 (94)	338 (78)
	TYFOON-72	130 (136/3)	196 (133/11)	402 (122/23)
THERESE	TYFN73	48 (178)	95 (118)	115 (68)
	TYFOON-72	58 (262/31)	95 (231/68)	109 (163/64)
TOTAL	TYFN73	688	1246	1365
	TYFOON-72	689	1246	1568
AVERAGE	TYFN73	137.6 (122)	249.2 (88)	341.3 (49)
	TYFOON-72	137.8 (196/17)	249.2 (179/50)	392.0 (119/46)

TOTAL RUN TIME: TYFN73 5.3 MIN

TYFOON-72 10.2 MIN

TABLE 4. RECURVE ERROR STATISTICS.

NUMBERS IN PARENTHESES ARE ANALOG POSITIONS EMPLOYED BY EACH PROGRAM.

STORM	PROGRAM	FORECAST ERRORS (IN NM) 24-HR	48-HR	72-HR
LOLA	TYFN73	68 (12)	410 (12)	964 (12)
	TYFOON-72	93 (30/0)	407 (30/0)	822 (30/0)
ALICE	TYFN73	27 (105)	116 (97)	320 (78)
	TYFOON-72	25 (125/2)	118 (123/8)	254 (115/29)
HELEN	TYFN73	39 (295)	138 (292)	625 (290)
	TYFOON-72	49 (445/6)	121 (439/13)	584 (426/9)
IDA	TYFN73	136 (114)	310 (113)	528 (109)
	TYFOON-72	126 (131/0)	303 (131/1)	502 (130/4)
NANCY	TYFN73	25 (24)	195 (23)	530 (21)
	TYFOON-72	50 (41/0)	259 (41/1)	587 (40/2)
TOTAL	TYFN73	295	1169	2967
	TYFOON-72	343	1208	2749
AVERAGE	TYFN73	59.0 (110)	233.8 (107)	593.4 (102)
	TYFOON-72	68.6 (154/2)	241.6 (153/5)	549.8 (148/9)

TOTAL RUN TIME: TYFN73 5.6 MIN

TYFOON-72 10.3 MIN

a. Dividing the analog data tape into two separate tapes, one for straight moving systems and one for recurving systems. This has already been accomplished (ODSI, 1973).

b. Recompute the regression coefficients and weighting factors based on the two categories of tapes listed above. This is presently in progress.

Implementation of these two items, it is hoped, will result in improved analog forecasts for all categories.

The affect of reducing the time envelope by 30% is reflected in the number of positions listed in Tables 2, 3, and 4. The ratio of analog positions used by TYFN73 to TYFOON-72, excluding extrapolated positions ranges from a low of 67.1% for straight movers at 72 hours, to a high of 73.4% for recurvers, also at 72 hours. The percent of positions extrapolated by TYFOON-72 varied from a low of 1.2% for the over water cases at 24 hours to a high of 38.7% for the straight movers at 72 hours.

Table 5 presents the overall summary for all cases grouped together. This reveals no significant differences between TYFN73 and TYFOON-72, with the exception of the time required to run each program. In this test, TYFN73 performed its functions about 46% faster than TYFOON-72. By forecast, TYFOON-72 was superior 22 times, TYFN73 20 times, and in two instances, both programs had the same error. Finally, the errors generated by both programs were always in the same general direction from the verifying best track positions.

TABLE 5 SUMMARY OF ERROR STATISTICS

STORM	PROGRAM	FORECAST ERRORS (IN NM) 24-HR	48-HR	72-HR	RUN TIME (MIN)
ALL	TYFN73	1487	3562	5979	16.5
	TYFOON-72	1538	3615	5986	30.7
AVERAGE	TYFN73	99.1	237.5	427.1	1.1
	TYFOON-72	102.5	241.0	427.6	2.0

4. SUMMARY

Based upon the results discussed in the previous section, the following conclusions may be made:

a. There was no significant difference betwwen the forecasts obtained from TYFN73 and TYFOON-72.

b. The reduction of the time envelope from ±50 days to ±35 days did not adversely affect the TYFOON analog forecasts.

c. Elimination of the extrapolation feature did not degrade the TYFOON analog forecasts.

d. The difference in computer run time between TYFN73 and TYFOON-72 is of major significance.

As a result of this test, FLEWEACEN/JTWC Guam has made TYFN73 operational and will use it during the 1974 season. With the availability of three data tapes (combined, straight, and recurve) and a more efficient program, greater flexibility in the use of the analog forecasting concept is now available. The result, hopefully, will be more accurate tropical cyclone forecasts.

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